IMPROVEMENTS TO OPERATIONAL STATISTICAL TROPICAL CYCLONE INTENSITY FORECAST MODELS

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OUTLINE

1. Modifying Statistical Hurricane Intensity Prediction Scheme (SHIPS) and Logistic Growth Equation Model (LGEM) to use daily Sea Surface Temperature (SST) and depth-averaged temperature
2. Adding tropical cyclone (TC) structure forecasts to SHIPS/LGEM

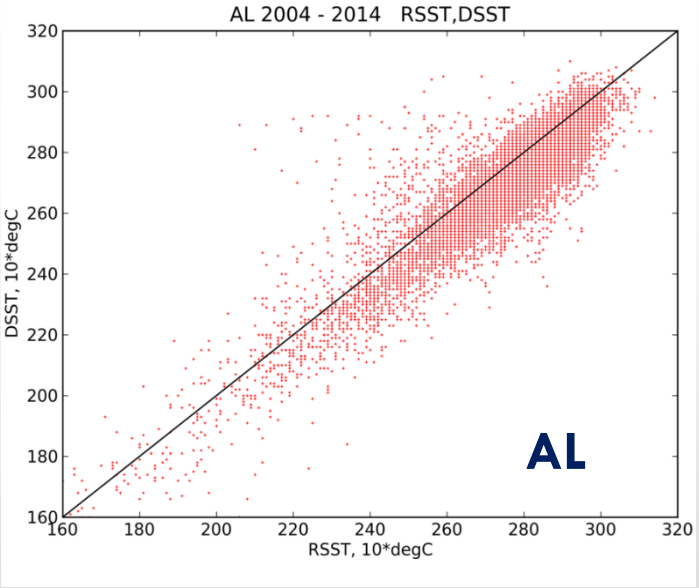
MODIFYING SHIPS/LGEM TO USE DAILY SST

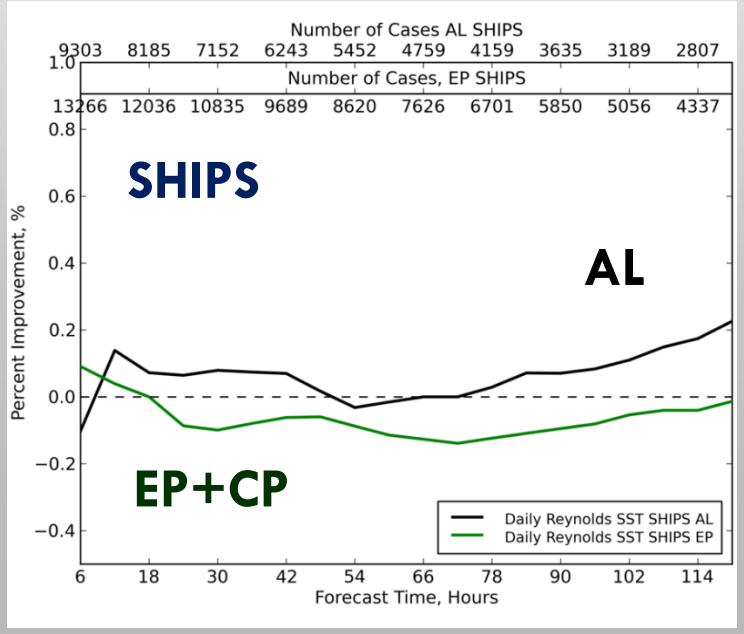
Operational SHIPS/LGEM uses weekly Reynolds SST data (RSST)

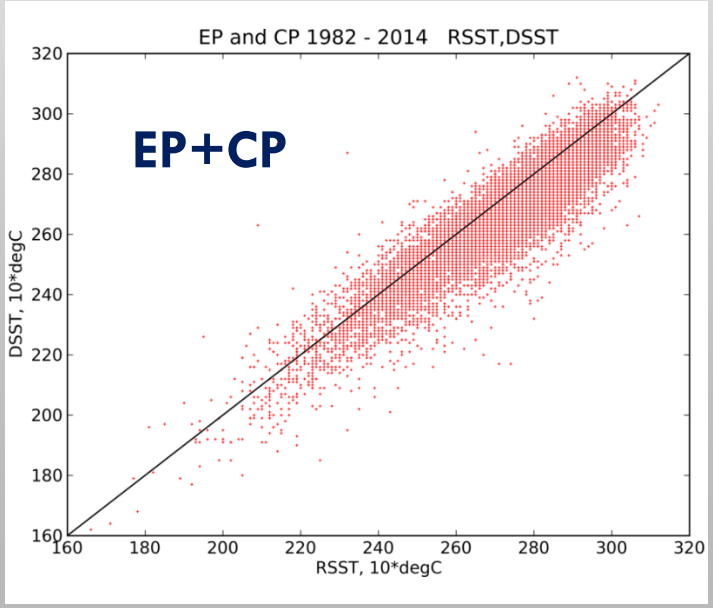
- **Created database of daily Reynolds SST (DSST) back to 1982:**
  - Developed software to put DSST in the format of SHIPS input files
  - Interpolated DSST to fill land, ice, and missing values. That makes the dataset similar to RSST and simplifies data interpolation.
- **SHIPS/LGEM code has been modified to work with daily SST**
- **Run dependent sample statistical tests using 1982 – 2014 data.** Derived new regression coefficients.
- **Completed retrospective runs with various settings for 2004 - 2015** to ensure that the code has not been broken by changes and to evaluate the impact of DSST on forecasts

DEPENDENT SAMPLE STATISTICS 1982 - 2014

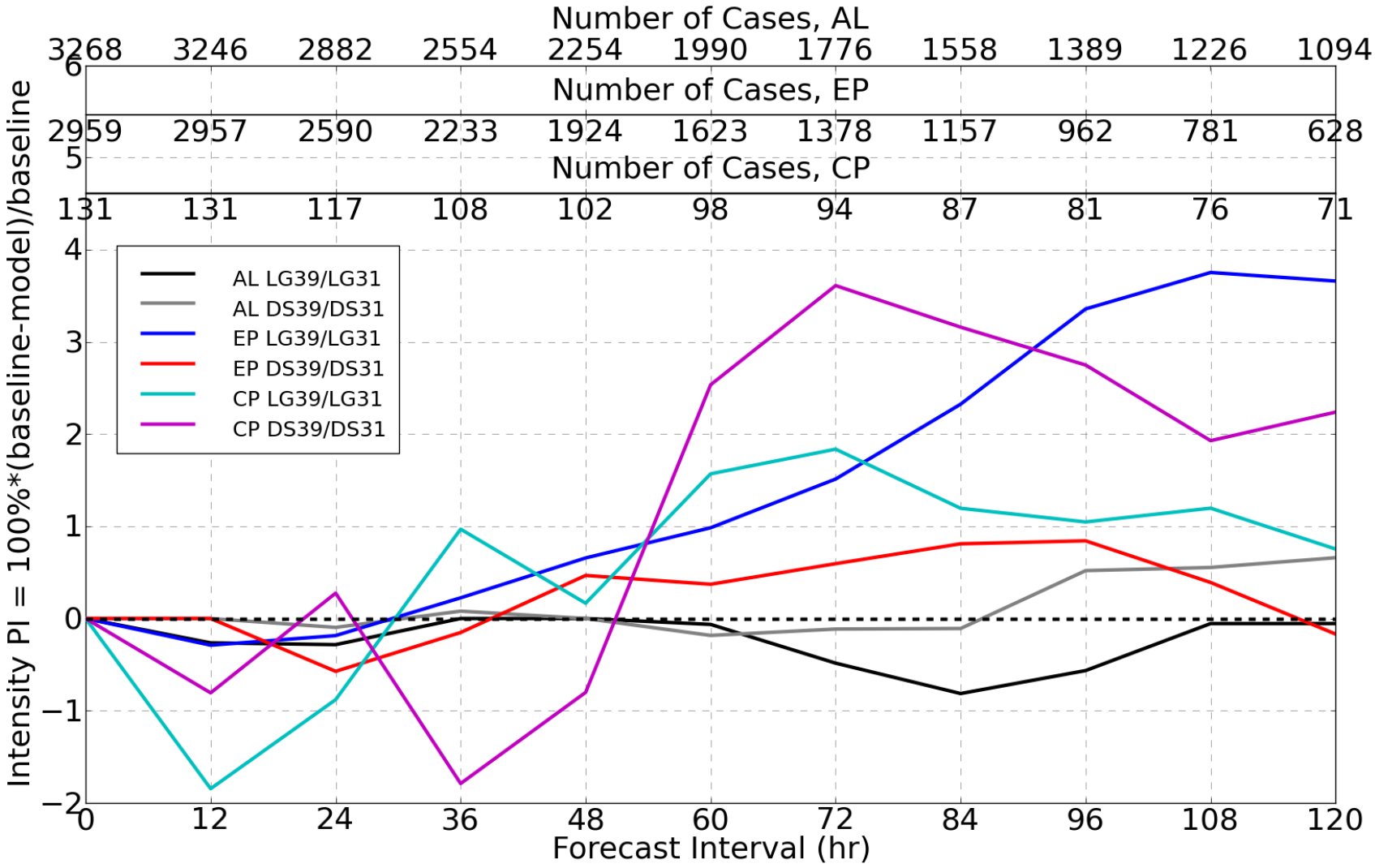
- DSST is in most cases colder than RSST for both AL and EP
- Both AL and combined EP/CP SHIPS forecasts errors with DSST stay similar to errors with RSST
- These results are consistent with the preliminary dependent sample statistics







SHIPS/LGEM VERIFICATION MAE: 2004-2014



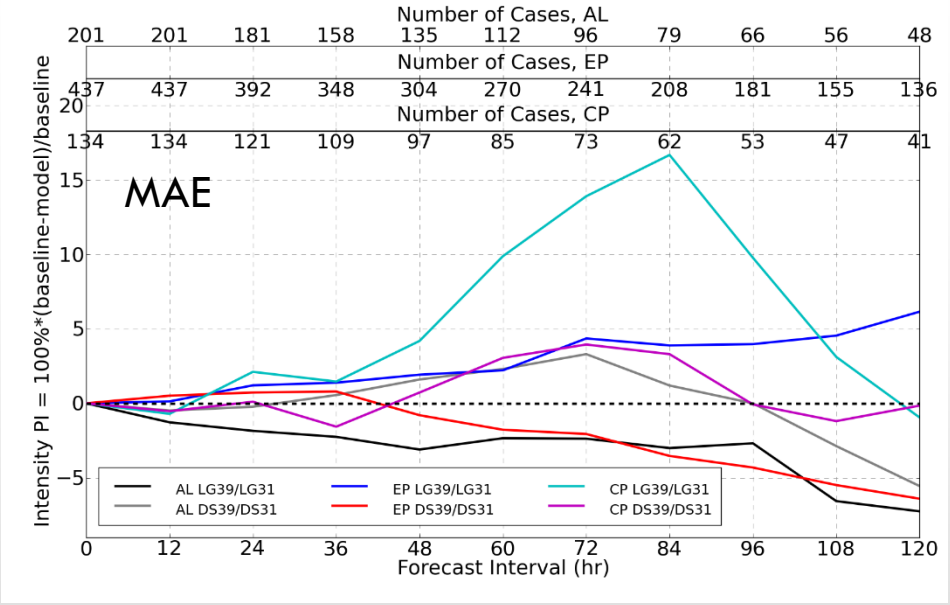
1. DS31, LG31 – weekly Reynolds SST 2. DS39, LG39 – daily Reynolds SST

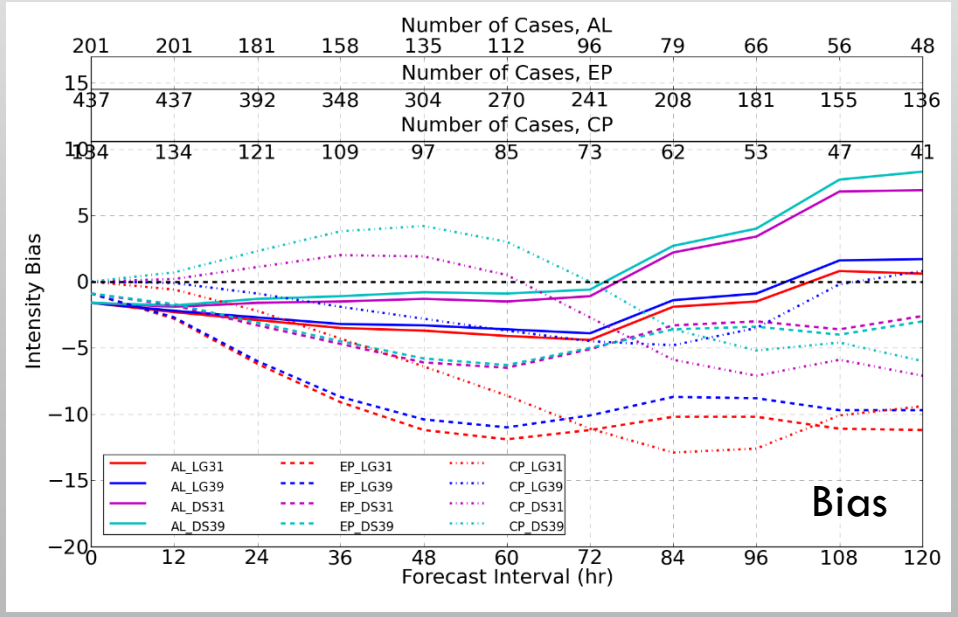
SHIPS/LGEM VERIFICATION 2015

MAE	SHIPS	LGEM
AL	Smaller	larger
EP	0-36 hr: smaller > 48 hr: larger	smaller
CP	0-36 hr: larger > 48 hr: smaller	0-12 hr: larger > 12 hr: smaller

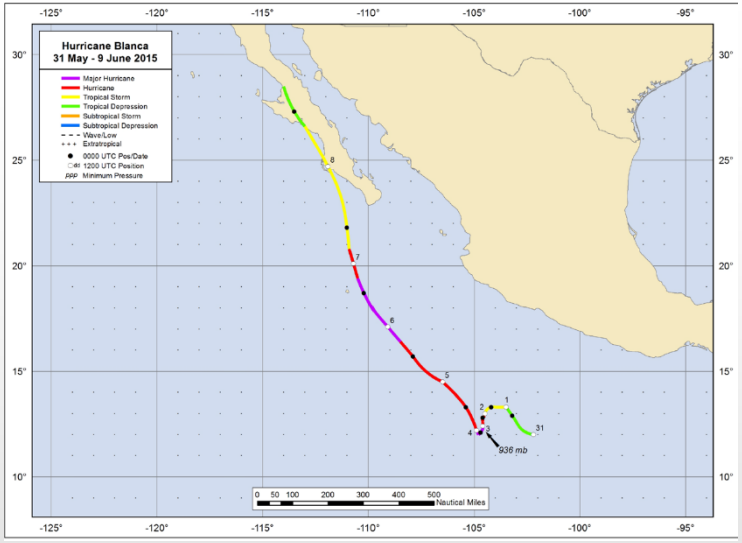
Bias	SHIPS	LGEM
AL	0-72 hr: smaller > 72 hr: larger	0-108hr: smaller > 72 hr: larger
EP	smaller	similar
CP	0-72 hr: larger > 48 hr: smaller	smaller

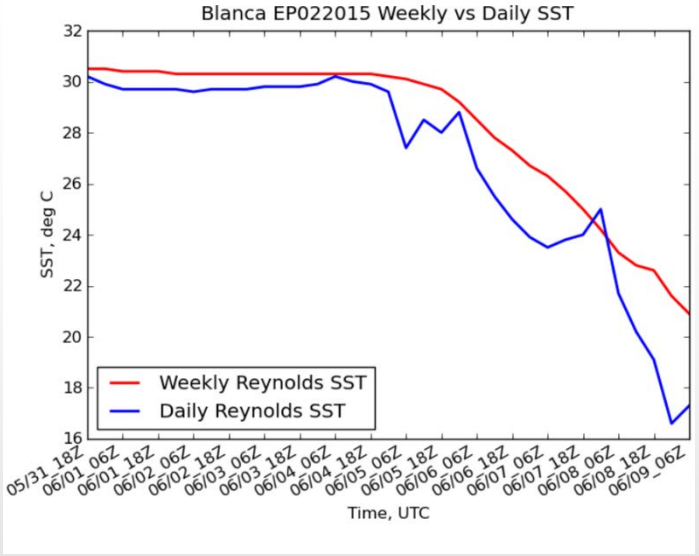
DS31, LG31 – weekly Reynolds SST
DS39, LG39 – daily Reynolds SST

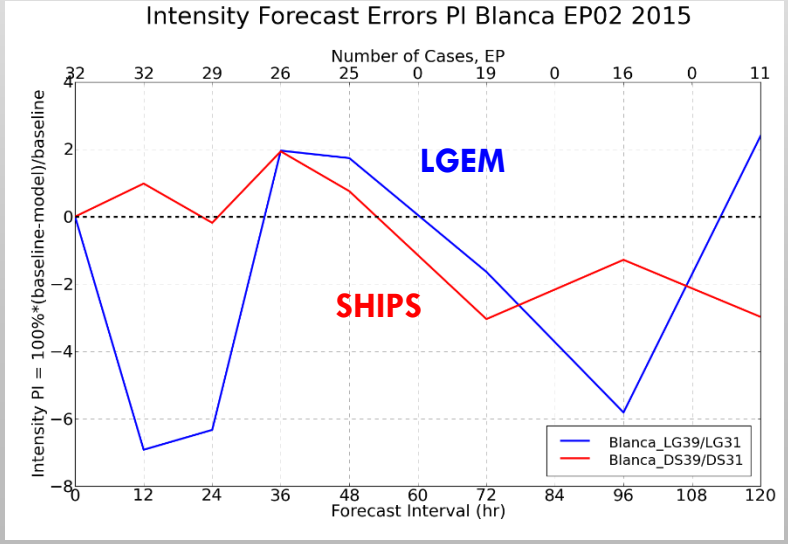


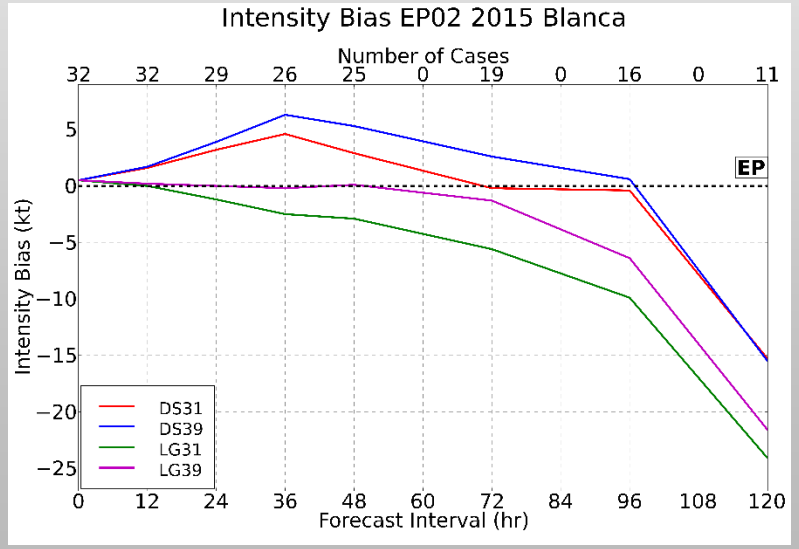


BLANCA EP02 2015



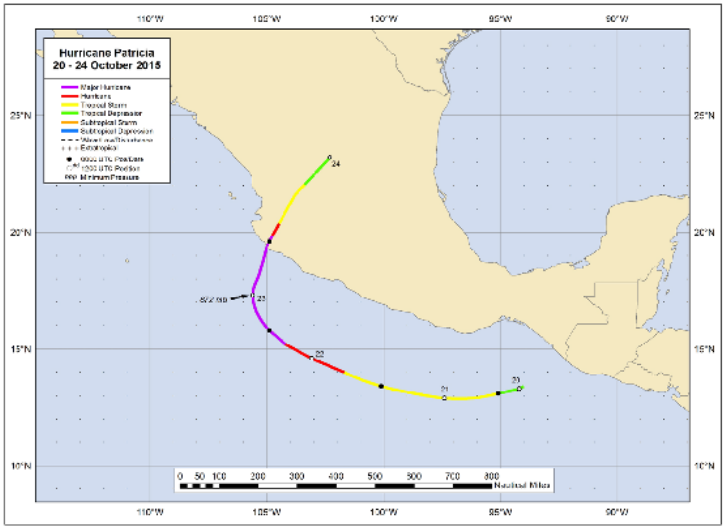


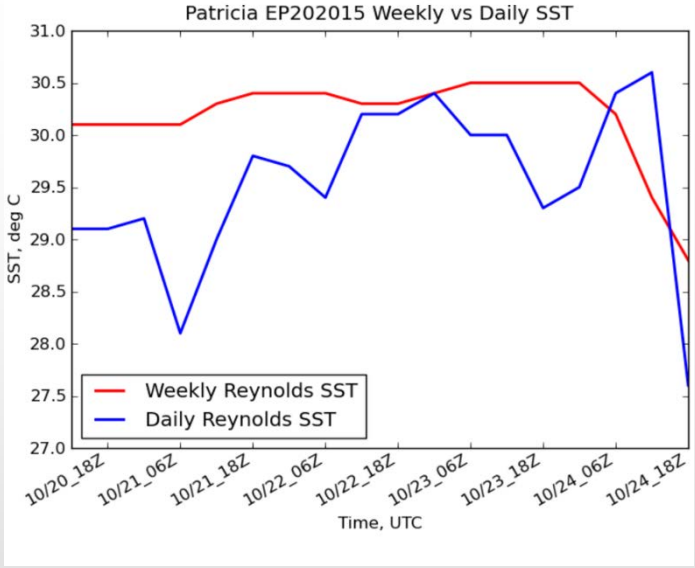


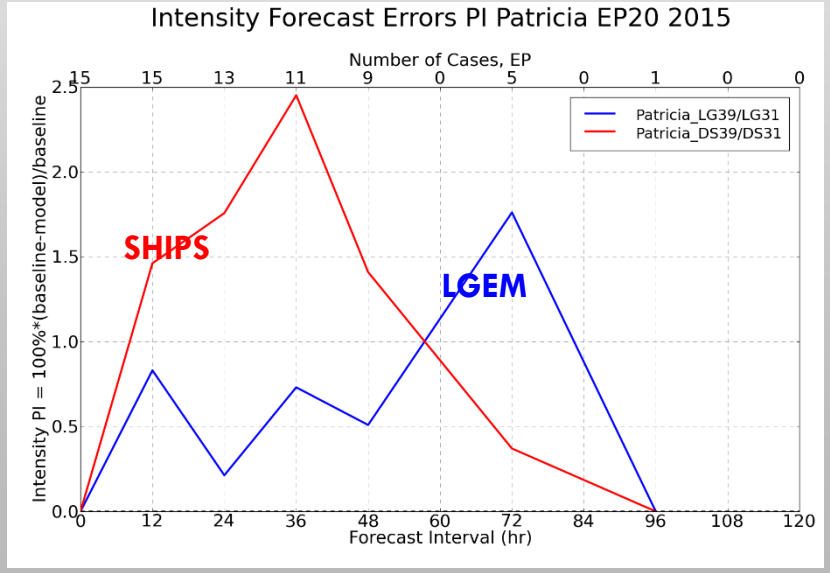


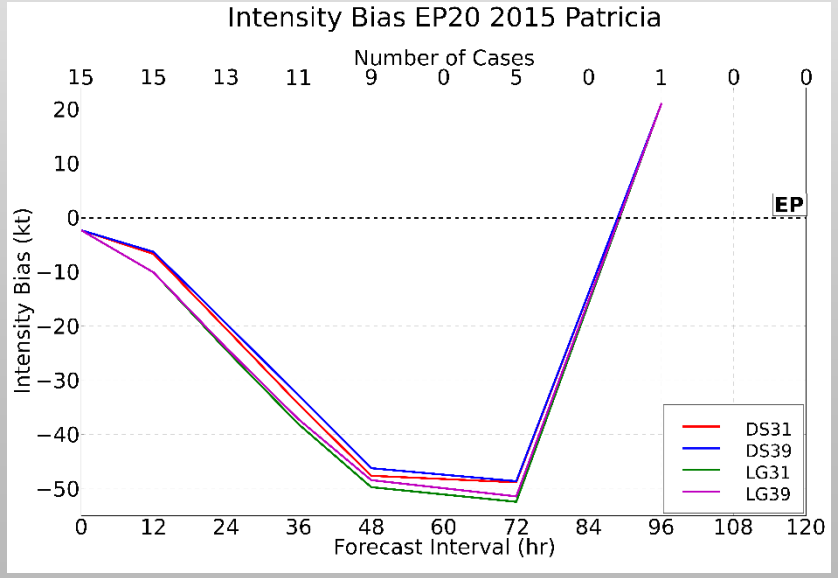
1. DS31, LG31 – weekly Reynolds SST 2. DS39, LG39 – daily Reynolds SST

PATRICIA EP20 2015 THE STRONGEST AL/EP STORM ON RECORD









1. DS31, LG31 – weekly Reynolds SST 2. DS39, LG39 – daily Reynolds SST

FURTHER STEPS:

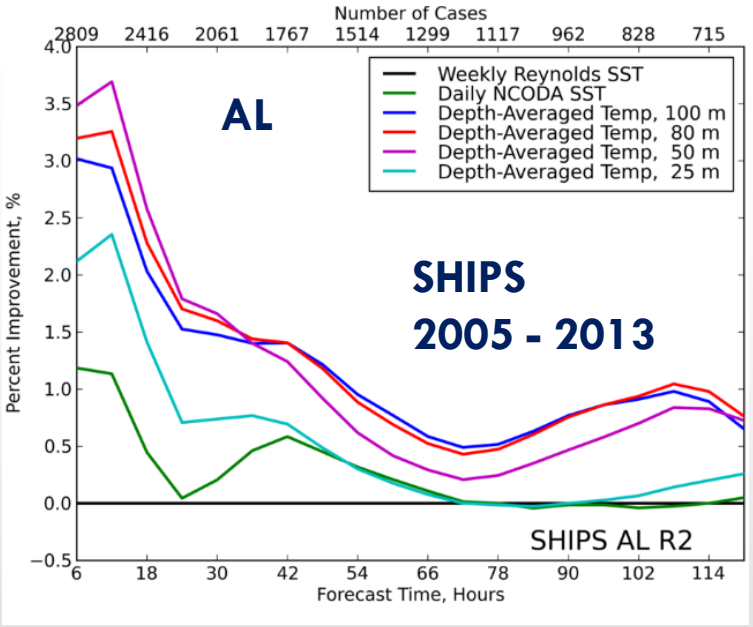
1) Use daily SST to estimate a vertical average of the initial (pre-hurricane) ocean ***T*** *(Price, 2009)*, which is better estimate of ocean-TC interaction than OHC

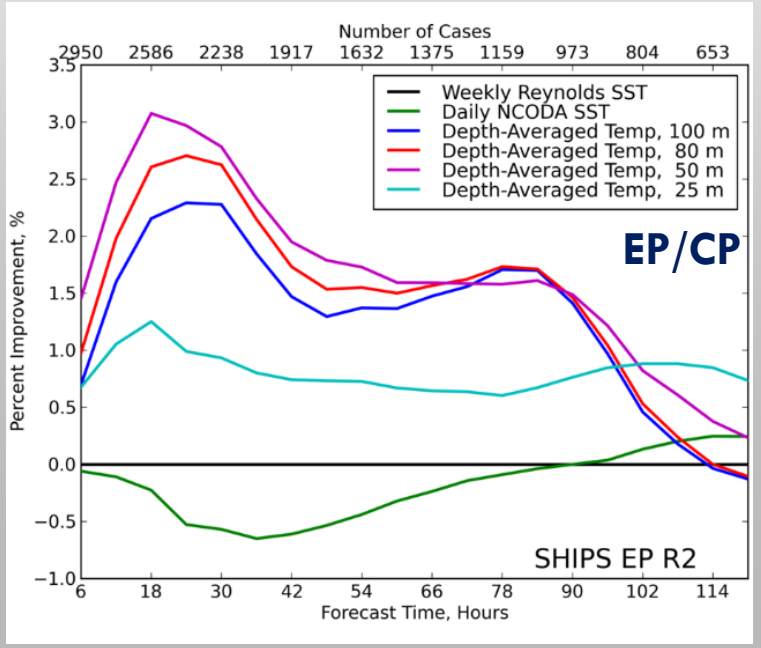
$$T_{\overline{d}}(x,y) = \int_{-d}^{0} T_i\ (x,y,z)dz,$$

d – depth of vertical mixing caused by TC

2) Begin SHIPS parallel runs with daily SST and $T_{\overline{d}}$

3) Make $T_{\overline{d}}$ a function of storm translation speed

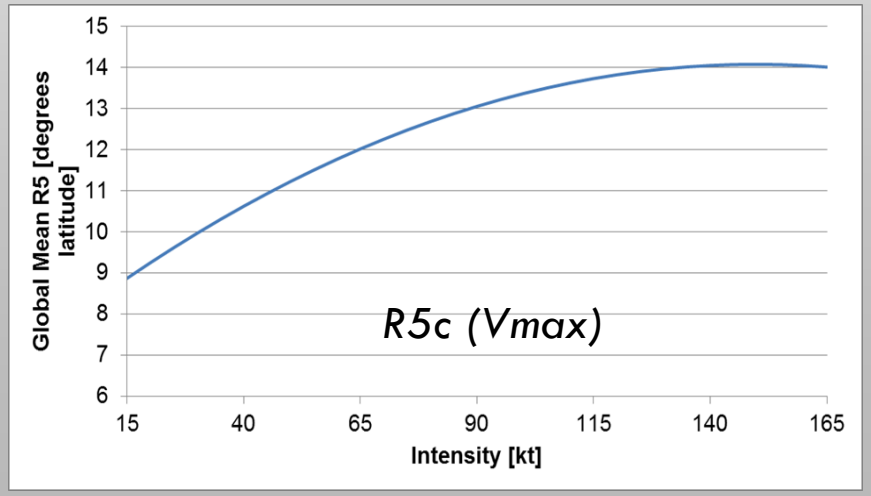




ADDING TC STRUCTURE FORECASTS TO SHIPS/LGEM

- A statistical-dynamical method has been developed to estimate wind radii and MSLP for global tropical cyclone basins
  - Satellite – based size estimates are used as the independent variable
  - Predictors come from the SHIPS diagnostics (NHC, JTWC)
  - Any intensity forecast can be applied
- Use IR-based TC size (R5, Knaff et al. 2014) as an objective and consistent measure of TC size

$R5 = f(Vmax, Lat)$ $\quad R5_c = 7.653 + \left(\frac{Vm}{11.651}\right) - \left(\frac{Vm}{59.067}\right)^2 \quad F_{R5} = \frac{R5}{R5_c}$



ΔF_{R5} : independent variable

- Six-hourly R5 -> F_{R5} -> $\Delta F_{R5\ (from\ t=0)}$ created for forecast leads of 6,12,18,…..120h ,

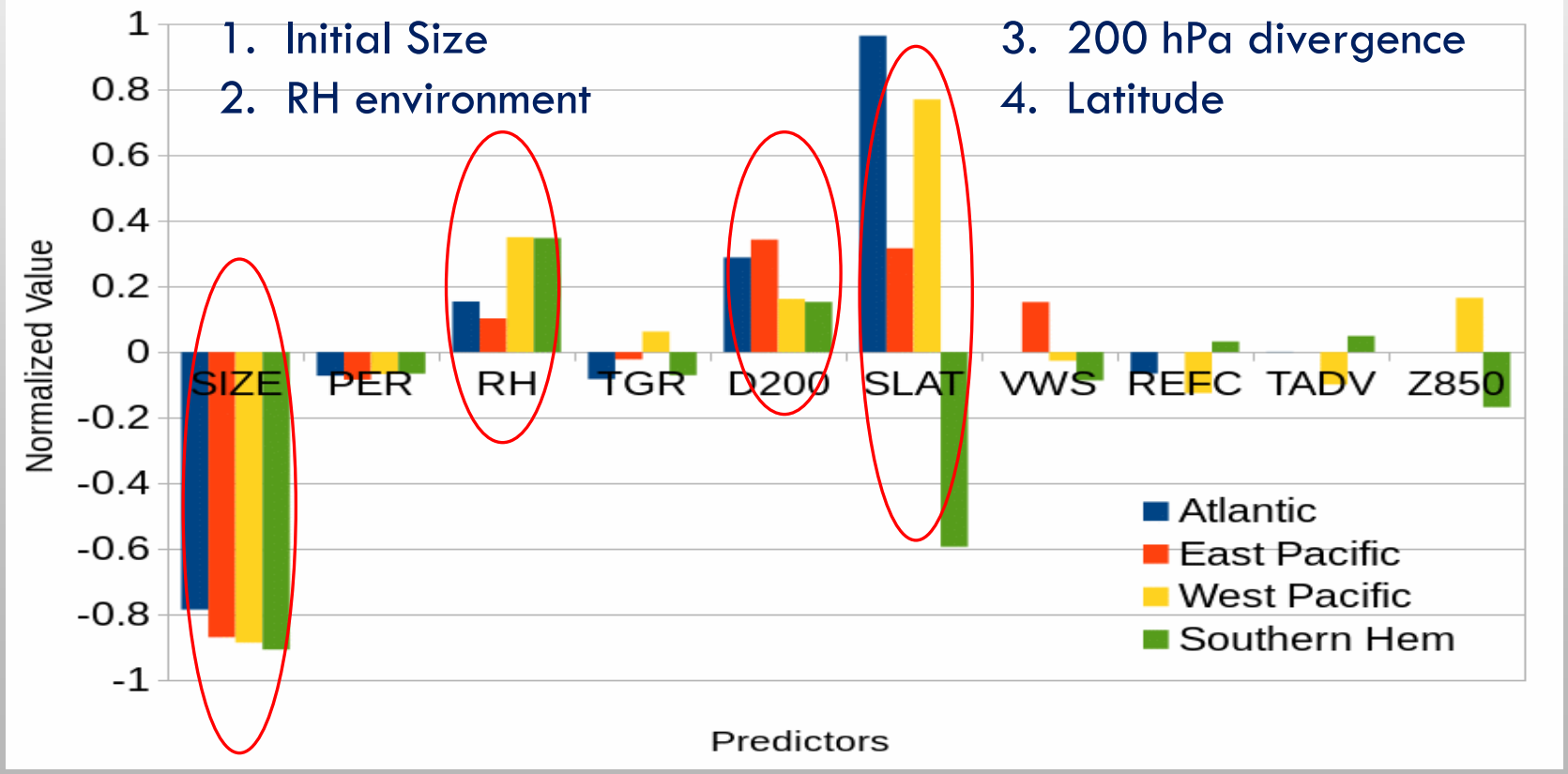
$$\frac{dF_{R5}}{dt} = C(x_1, x_2, \ldots, x_n)$$

x's : dependent variables

NORMALIZED REGRESSION COEFFICIENTS (48 HR)

- (Size) initial FR5
- (Vm) current intensity
- (Per) 12-h intensity trend
- (Pi) potential intensity
- (Rh) relative humidity (700-500hpa) (200-800 km)
- (Tgr) T gradient, 850 and 700 hpa
- (D200) 200 hpa divergence (0-1000 km)
- (Slat) sine of latitude
- (Sst) sea surface temperature
- (Refc) relative eddy flux convergence (100-600 km)
- (Tadv) T advection, 850 and 700 hpa(0-500 km)
- (Vws) vertical wind shear (200-850 hpa) (0 – 500 km)
- (Z850) vorticity at 850 hpa (0-1000 km)

Biggest Contributors (excluding initial intensity, SST and potential intensity)

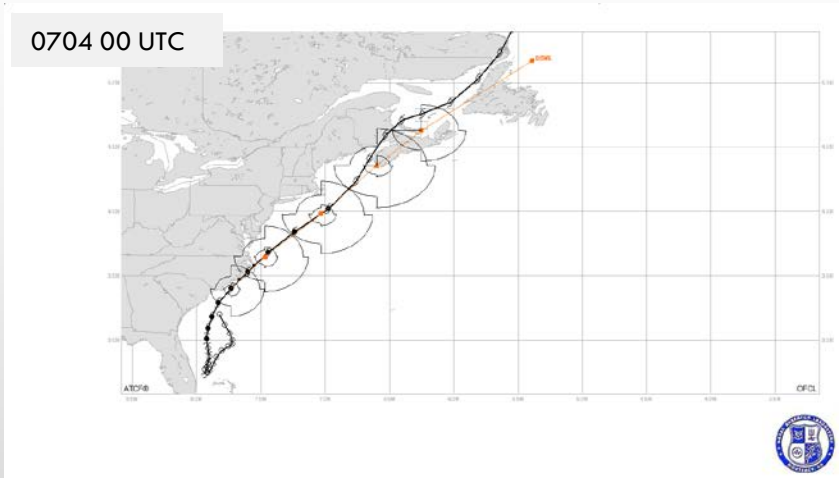


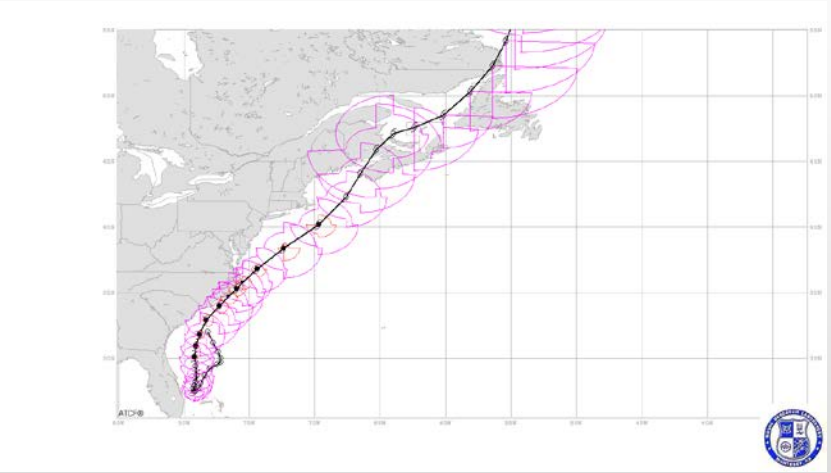
Forecast: Arthur (2014) 07/03 00UTC (All the Issues)

Issues:

1) Land : Wind radii constrained by the coast

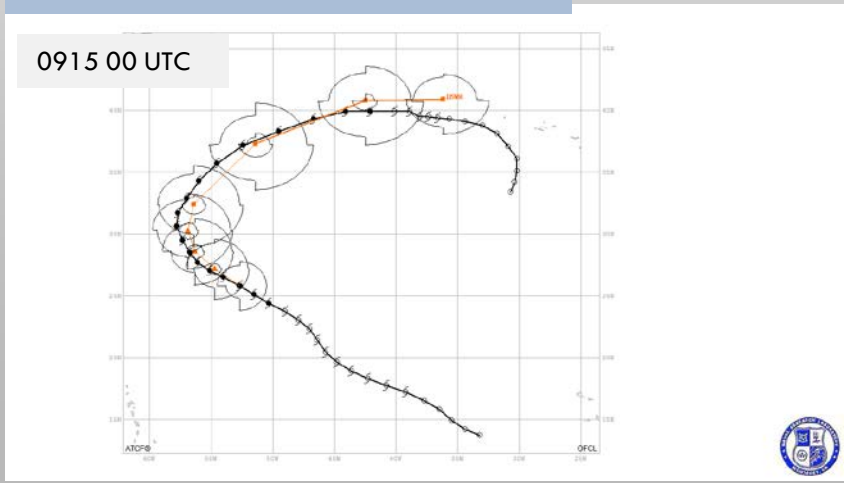
2) Ill-timed growth : Grew too early

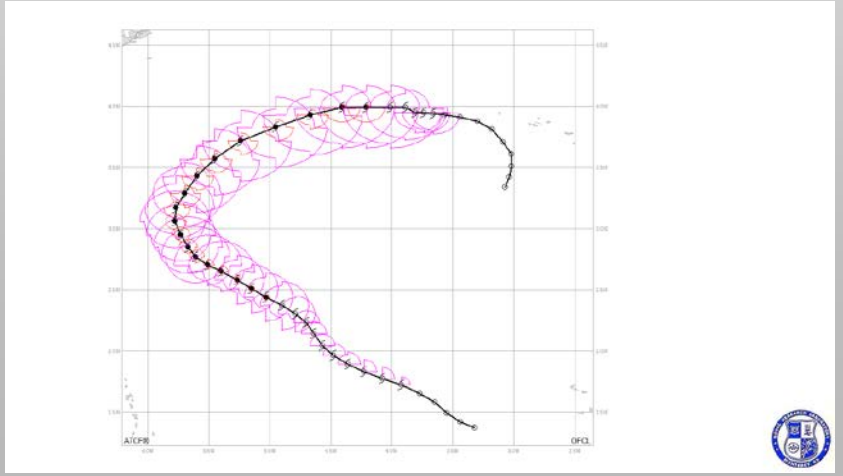




Forecast: Edouard (2014) (produced good forecasts)

Good overall performance

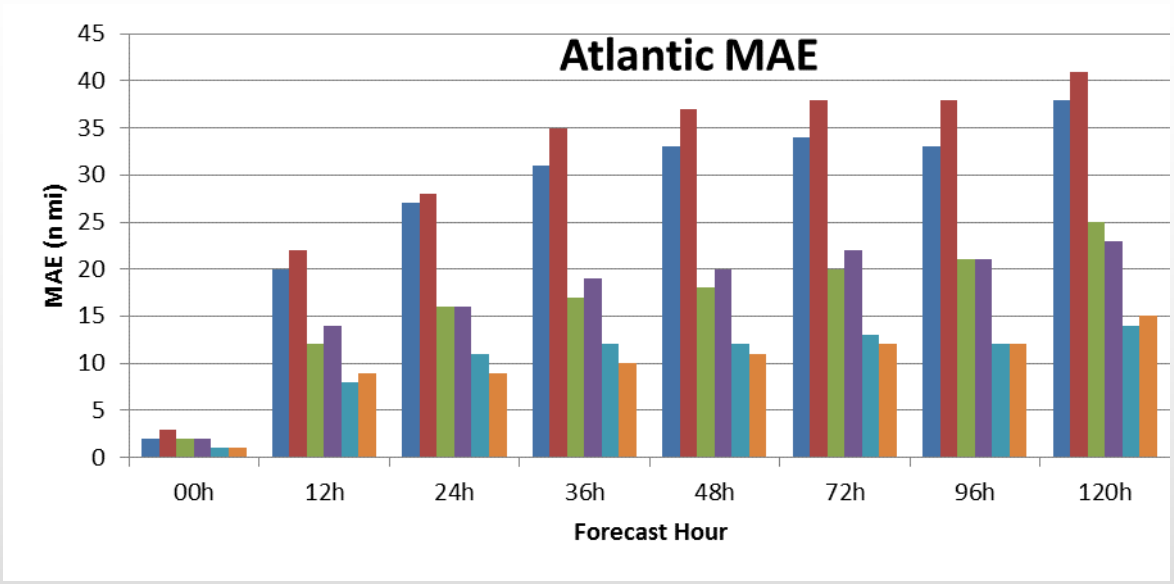


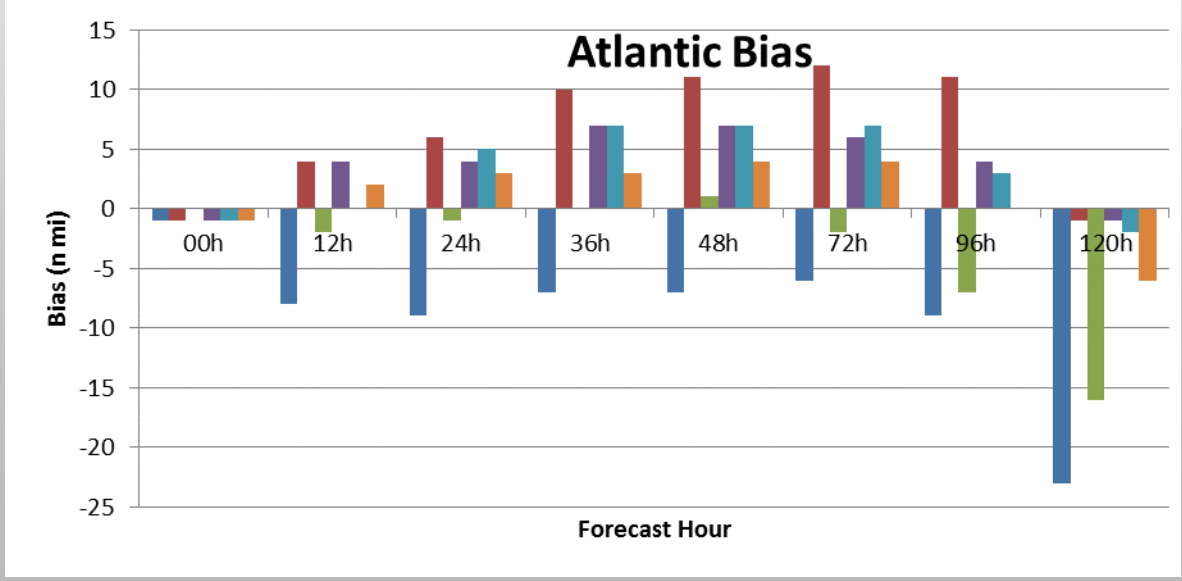


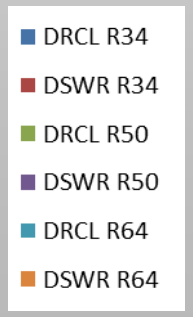
VALIDATION (2014-2015) – INDEPENDENT: AL

- MAE: DSWR vs DRCL errors
  - R34 larger
  - R50: larger or similar
  - R64: similar, sometimes smaller
- Bias:
  - R34, R50:
    - DRCL – negative
    - DSWR – positive
  - R64: both positive
- **Overall: need to address biases**

No statistically significant difference when accounting for serial and radial correlations





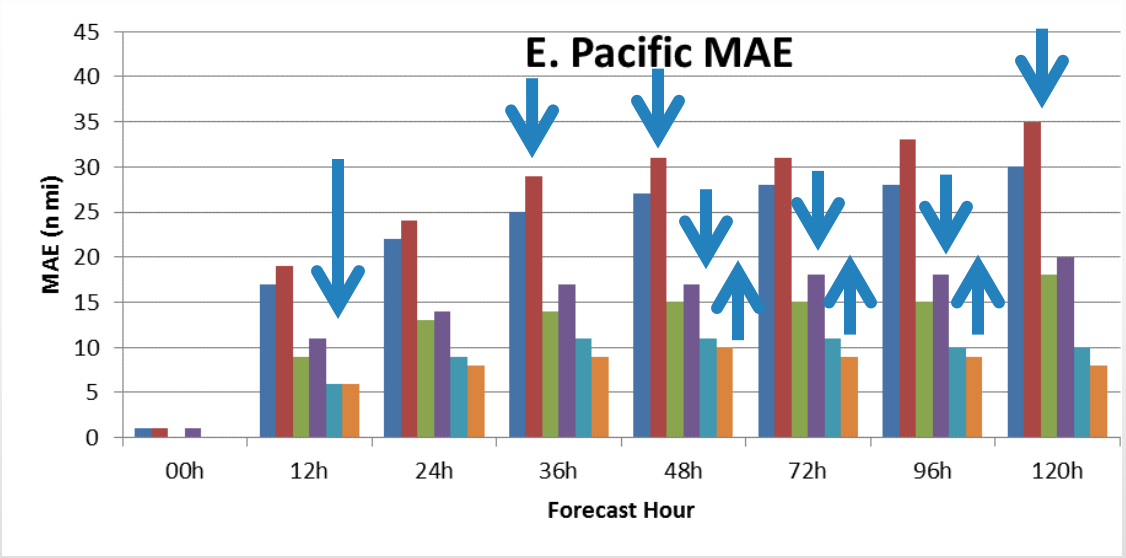


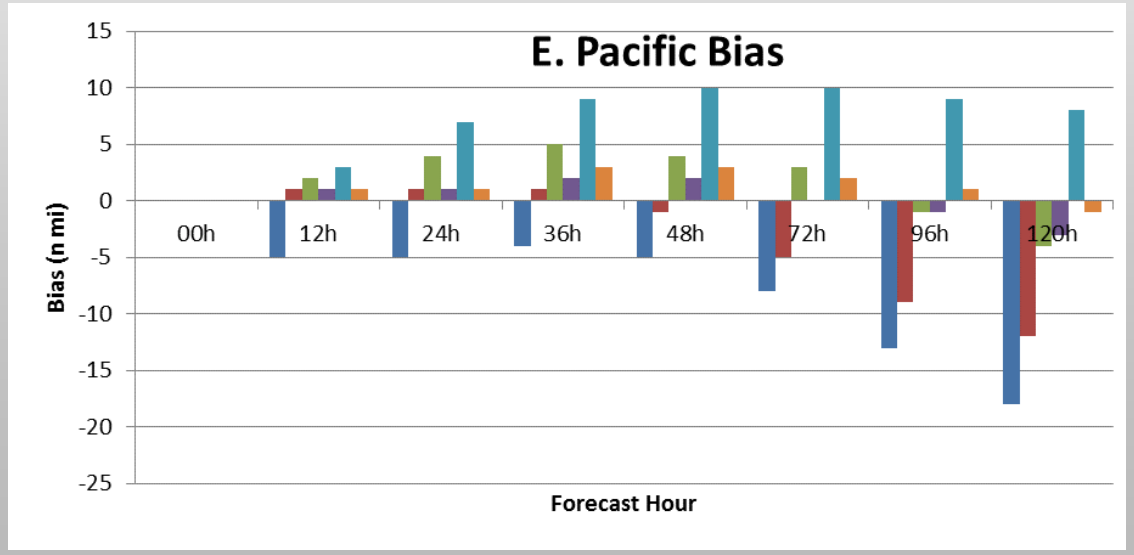
Track: DSWR: OFCI DRCL: OFCL Intensity: DSWR: SHIPS DRCL: OFC

Results based on predictors and intensities created in real-time at NHC

INDEPENDENT VALIDATION (2014-2015) – EP

- MAE; DSWR vs DRCL errors
  - R34, R50: larger
  - R64: smaller
- Bias:
  - R34:
    - DRCP – negative;
    - DSWR – small positive or negative
  - R50:
    - DRCL – negative
    - DSWR – positive; negative after 96 hr
  - R64:
    - DRCL – strong positive
    - DSWR – small positive
- **Overall:**
  - **Slightly better for R64**
  - **In many cases biases are smaller than DRCL**
  - **Need to address biases**





Statistically significant (90%) difference when accounting for serial and radial correlations (arrows)

Track: DSWR: OFCI DRCL: OFCL Intensity: DSWR: SHIPS DRCL: OFC

Results based on predictors and intensities created in real-time at NHC

FURTHER STEPS:

- 2014-2015 forecasts provided to NHC in December, 2015
- Issues with biases will be addressed before the hurricane season
- Algorithm will be run on all global basins at CIRA for 2016 AL season
- Modular F90 code developed and ready for use at NHC
- Plans to include this model in the ATCF updates (May) to JTWC

SUMMARY AND CONCLUSIONS

- **SHIPS/LGEM with daily Reynolds SST:**
  - **Created database of daily Reynolds SST** in SHIPS/LGEM input format for 1982 -2015
  - Data were interpolated to fill missing, land, and ice values to make dataset similar to weekly SST and simplify further interpolation
  - **Completed dependent statistical tests using 1982 – 2014 data,** derived new regression coefficients for models.
  - **Completed and verified SHIPS/LGEM reruns for 2004 – 2015.**
  - **Results: slight improvement for intensity forecasts in some cases and reduced biases,** as expected
- **TC structure forecasts:**
  - **Database of TC size predictors for 1996 – 2015 created**
  - A **statistical-dynamical method developed to estimate wind radii and MSLP for global TCs** using satellite data and SHIPS/LGEM intensities. 1996-2013 data used for development.
  - Results: **verified using 2014-2015 data**
  - Results: more diverse forecasts, but not superior to the baseline DRCL in the AL and EP
- **Future work:**
  - **Add depth-averaged temperature at constant depth** to SHIPS/LGEM
  - **Address bias** issues in the TC structure forecasts
  - Make depth-averaged temperature a function of TC translation speed
  - **Run modified SHIPS/LGEM and TC structure forecasts in real-time for 2016 AL season**